



An assessment of the tropical Humidity – Temperature covariance using AIRS

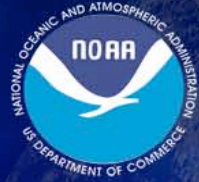
Antonia Gambacorta, UMBC/PSGS

Chris Barnet, NOAA/NESDIS

Brian Soden, Univ. of Miami

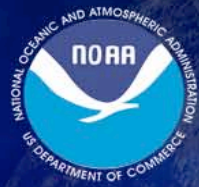
Larrabee Strow, UMBC

AIRS SCIENCE MEETING, October 10, 2007



Outline

- We investigate the horizontal and vertical structure of covariance between water vapor and temperature in the tropical troposphere using AIRS
- We compare with previous study (radiosondes, ECMWF, GCMs) which have focused only on the covariance of tropical mean quantities, and have shown a general *uniform positive correlation through the whole troposphere*
- AIRS high spectral resolution and the radiance cloud clearing algorithm allow for high vertical resolution and excellent spatial coverage respectively. This enables a more comprehensive analysis than has previously been possible.
- AIRS shows large spatial gradient in the local covariance between water vapor and temperature
 - Submitted paper: A. Gambacorta, C. Barnet, B. Soden, L. Strow, *"An assessment of the tropical humidity-temperature covariance using AIRS"*, GRL, 2007
- Implications for climate



Motivations

Water vapor is the most active greenhouse gas in regulating the radiation budget of the atmosphere

- **The Clausius –Claperyon equation:** $e_s \sim \exp(-1/T)$

↑ Temperature ↑ Moisture content ➡ **Positive Feedback**

- **Lindzen hypothesis:** the vertical distribution of water vapor in the tropics is characterized by three distinct regions: the convective domain of the boundary layer, the free tropical troposphere and the outflow domain of deep convection: the dependence of water vapor on temperature may be strongly height dependent

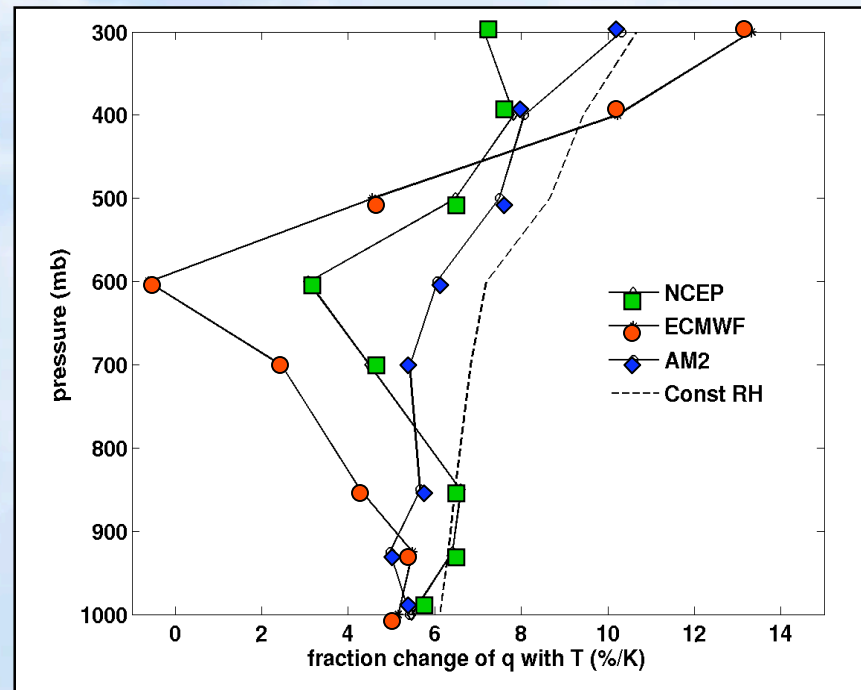
In the Upper Troposphere (UT):

↑ Temperature ↑ Convective Tower Height ↑ Precipitation ↓ UT moisture content
➡ **Drying negative Feedback**

Fractional change of q wrt T

$$dOLR \propto -d \ln q$$

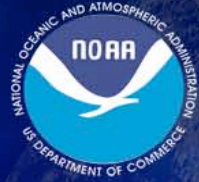
$$\frac{d \ln q}{dT} \sim \frac{1}{q_a} \frac{dq_m}{dT_m}$$



(Ref.: Huang and Soden, GRL, 2005)

q_a = Annual mean specific humidity
 q_m , T_m = monthly mean specific humidity and temperature

[Ref.: Huang and Soden, GRL, 2005; Sun and Oort, J.Climate, 1995;]



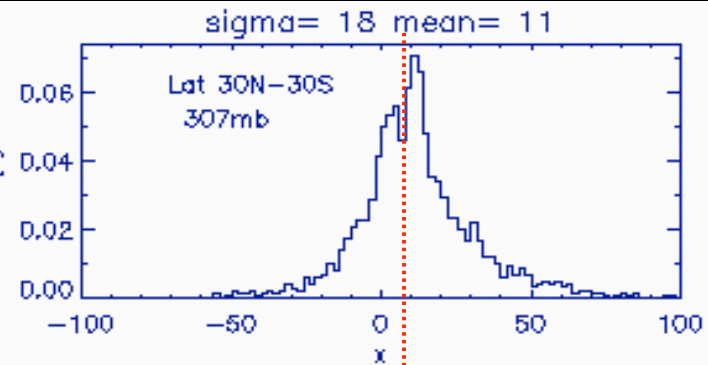
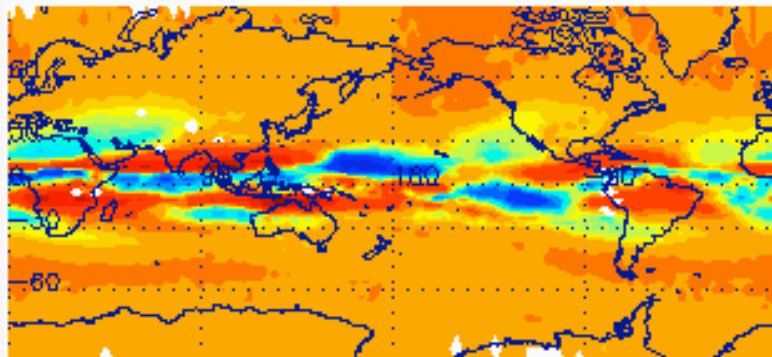
AIRS Dataset

- 3x3 degree gridded subsets of AIRS products (no spatial bias) from August 2003 to April 2007.
- NOAA emulation of version 5 retrieval algorithm, using a version 4–like rejection criterium:
 - To preserve whole accepted retrieval profiles
 - To increase sampling in tropical cloudy convective regions.
- **KEY Elements of AIRS database for this analysis:**
 - Cloud clearing: increase of the daily yield of observational data up to 80% (no clear-sky bias typical of satellite measurements)
 - Accurate retrieval algorithm: ~ 1 K for temperature; ~ 10 and 20% rms for water vapor in the tropical lower-middle and upper troposphere respectively
 - Uniform spatial coverage and high vertical resolution of ~ 2 -3km for T and ~ 2 km for WV

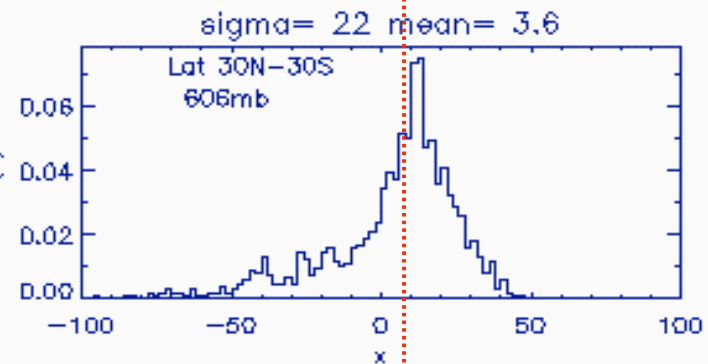
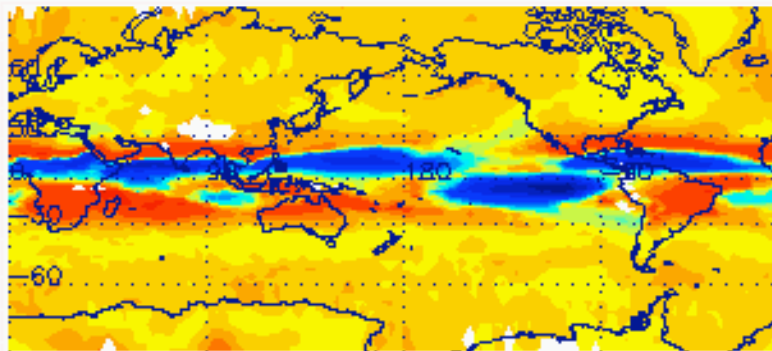
Fractional change of q wrt T , from AIRS

[$\frac{\Delta q}{q \Delta T}$, %/K]

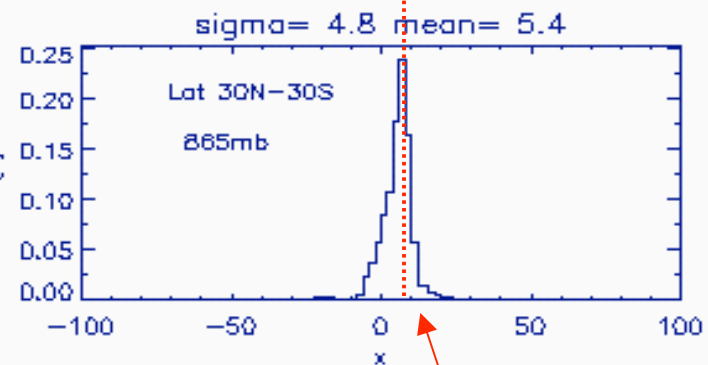
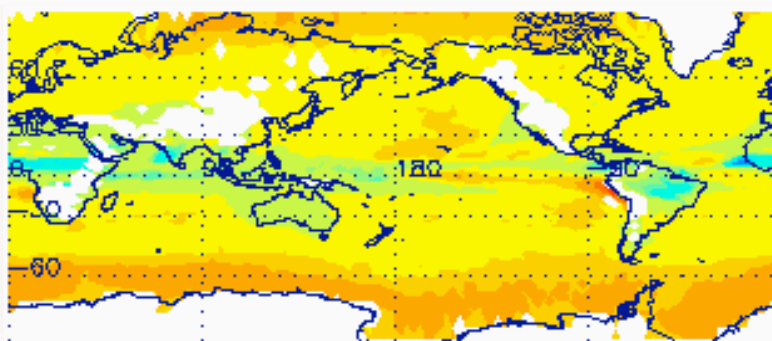
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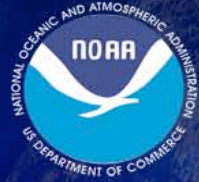
600mb



850mb



Clausius-Clapeyron regime $\sim 7\%/K$

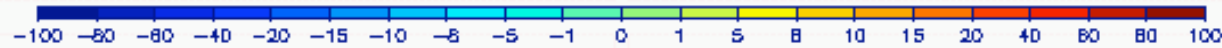
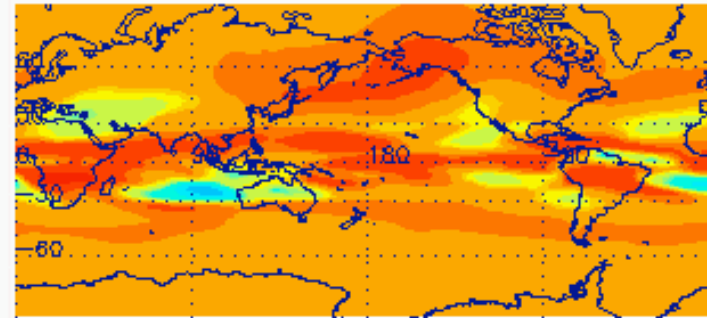
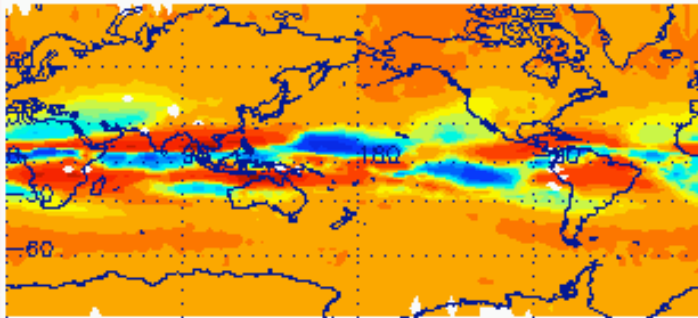


AIRS (left) vs NOAA GFDL model (right)

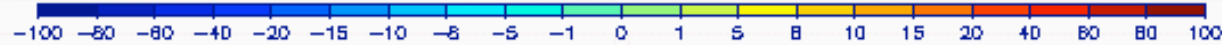
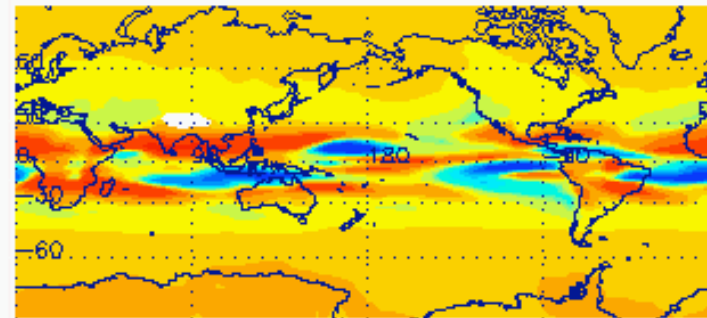
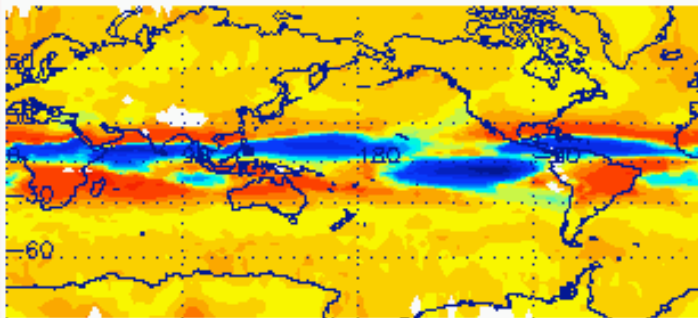
August 2003 – April 2007

January 1998 – December 2004

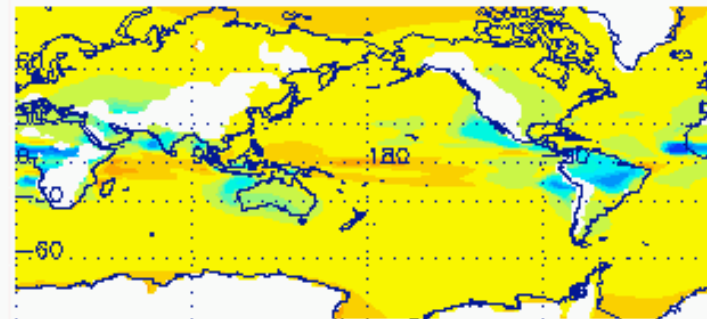
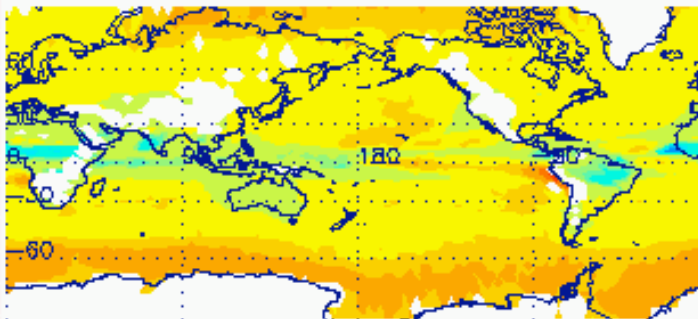
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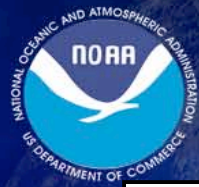


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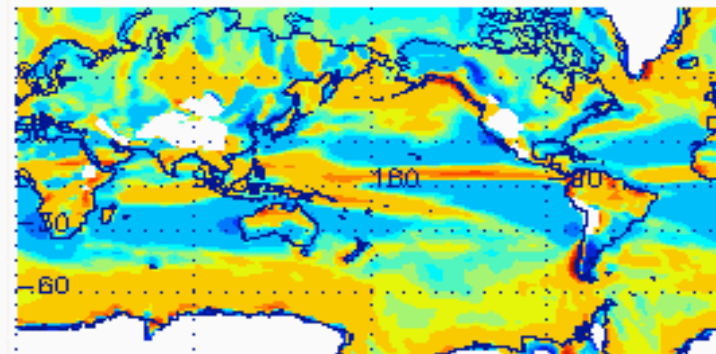
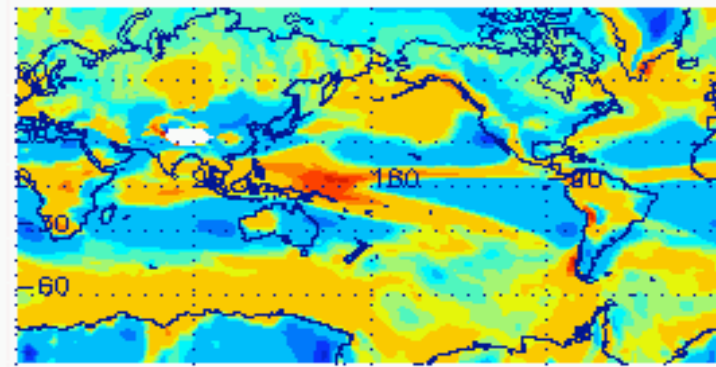
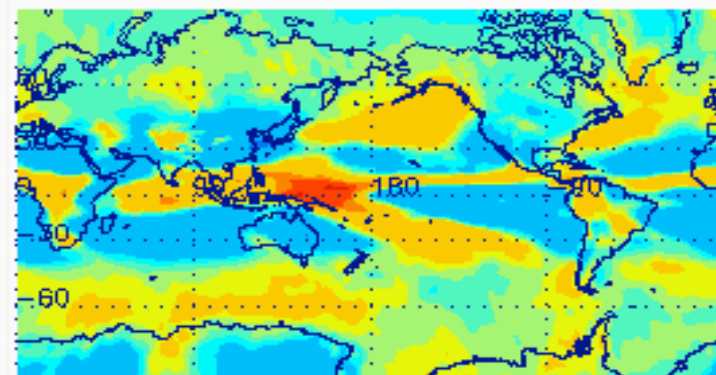
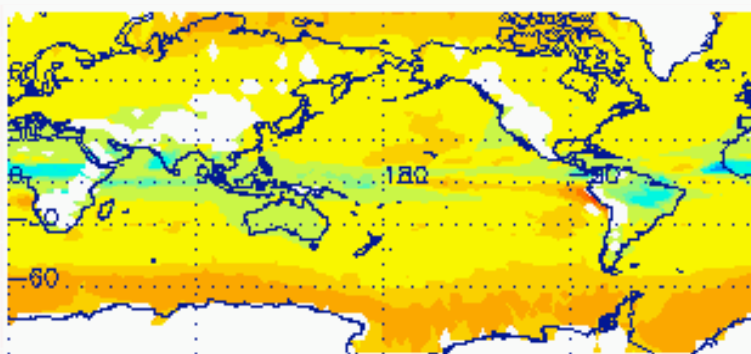
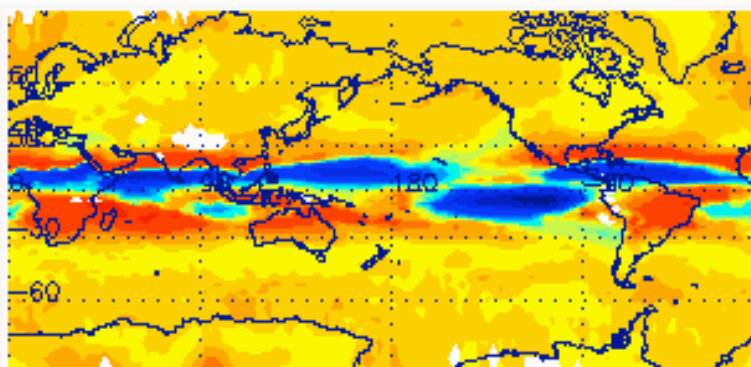
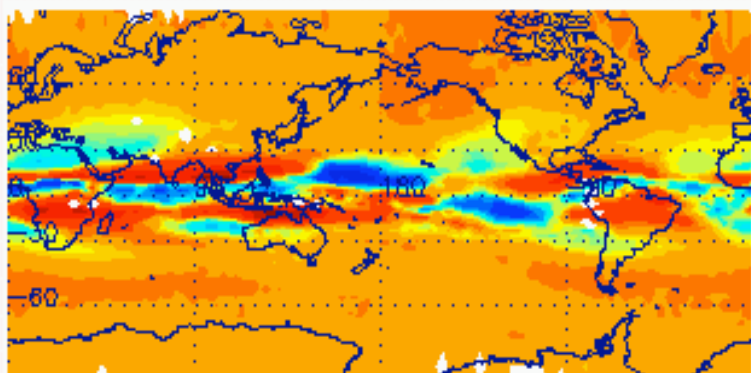
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Comparison with the NCEP vertical velocity field

August 2003 – December 2004





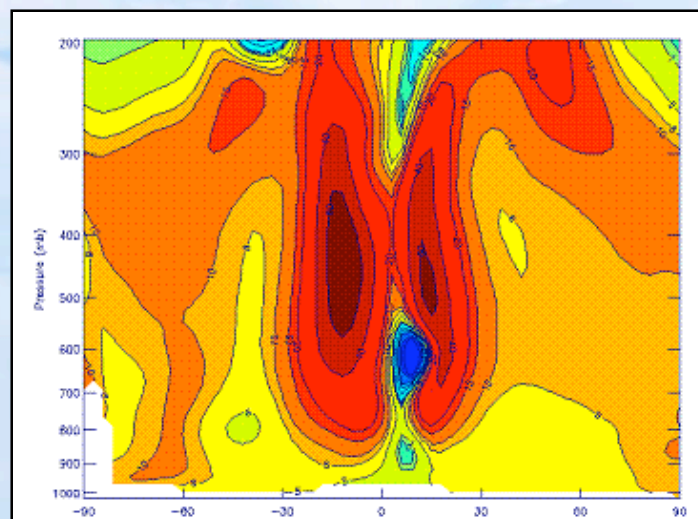
Fractional change of q wrt T , from AIRS

[ , %/K]

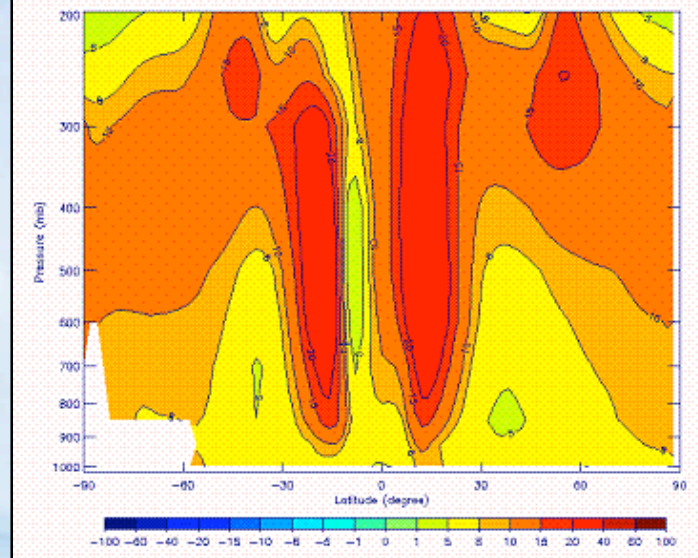
- AIRS shows a strong latitude-longitude dependence in the structure of the water vapor – temperature covariance, particularly in the free troposphere, where extended negative and positive covariance up to one order of magnitude larger than the Clausius-Claperyon eq. are found
- Highest positive responses found in the upper troposphere region
- Highest negative responses found in the middle troposphere region
- Comparisons with the NOAA GFDL model show same order of magnitude in the variability of the water vapor – temperature covariance values
- Other mechanisms regulating the water vapor distribution in the free tropical troposphere besides local temperature, appear to be connected to the patterns of the large scale circulation: regions of positive and negative covariance roughly resemble regions of the ascending and descending branches, respectively, of the tropical circulation

Zonal cross section

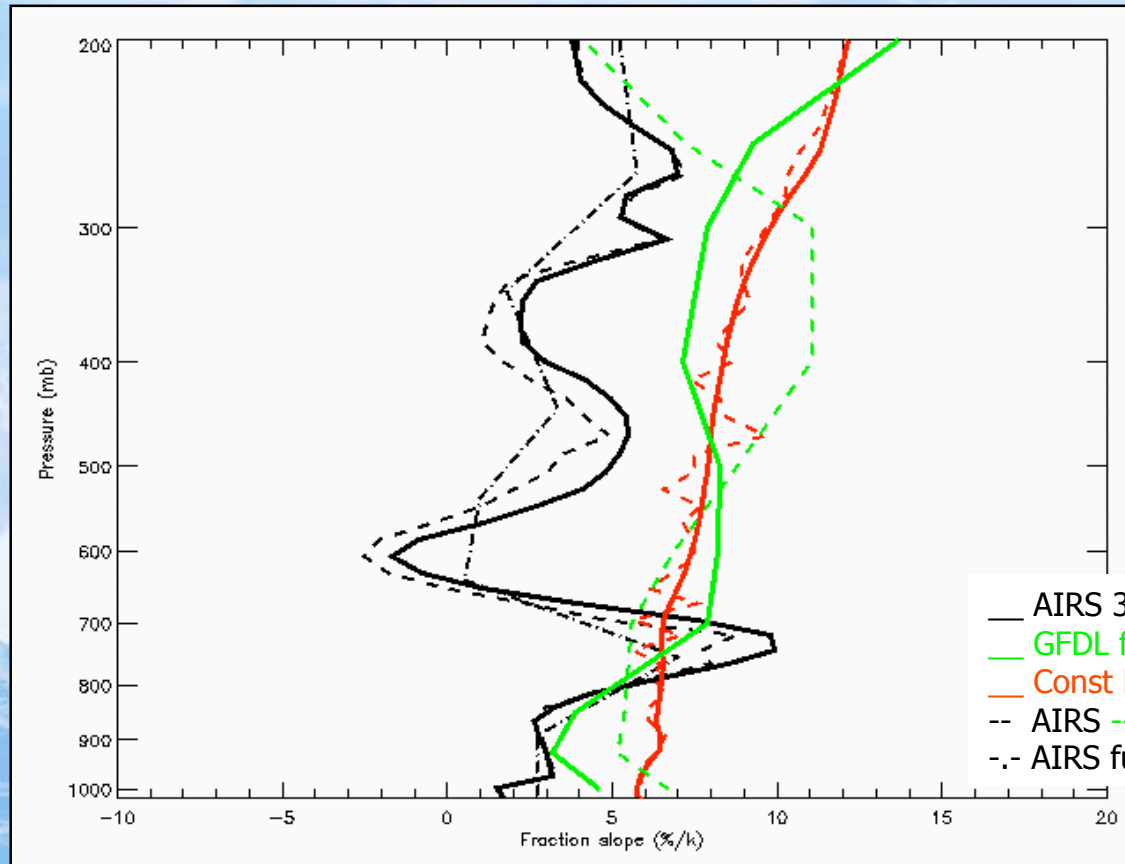
AIRS



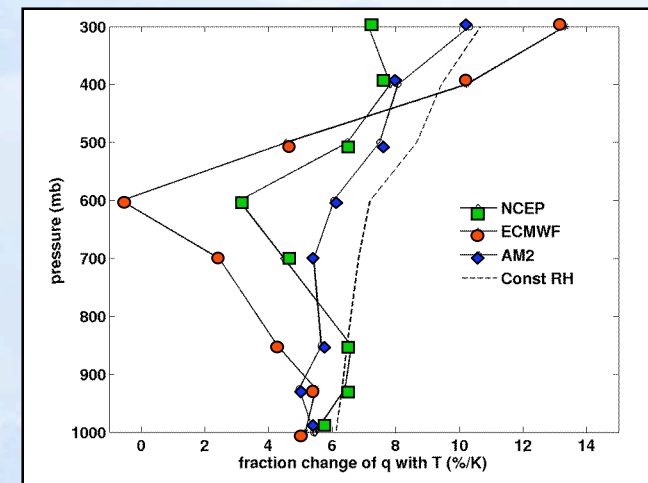
GFDL



Fractional changes of q and T tropical averages



- AIRS 3x3 degree spatial resolution
- GFDL full spatial resolution
- Const RH hypothesis
- AIRS -- GFDL on a common spatial subset
- .- AIRS further degraded on same vertical res of GFDL



(Ref.: Huang and Soden, GRL, 2005)

- When we average over the whole tropical domain, the regression slopes are of the **same order of magnitude of the Clausius Claperyon regime at ALL levels in the troposphere**

Conclusions

- Exploiting the high vertical resolution and excellent spatial coverage, the AIRS instrument shows a complex horizontal and vertical structure of the humidity-temperature covariance
- In the **upper troposphere** region, water vapor appears to be most strongly and **overall positively tied** to local temperature changes
- Negative correlations characterize extended regions of the free troposphere, particularly at mid altitude levels ($\sim 600\text{mb}$) where tropically averaged correlations become negative.
- Values **up to one order of magnitude larger than the Clausius-Clapeyron regime**, suggests that other processes besides local temperature, play a more important role in determining moisture changes in the free troposphere, and appear to be connected to the transport mechanisms of the large-scale tropical circulation.



Future works:

- Recent findings [Vecchi et al., *Nature*, 2006] of a weakening process of the tropical circulation due to anthropogenic forcing lead to new questions:
 - **What are these moistening and drying sources?**
 - **How do they relate to the tropical circulation?**
 - **What is their overall radiative role in the Earth's energy budget?**



